XV. "An Account of certain Experiments, on Aneroid Barometers, made at Kew Observatory, at the expense of the Meteorological Committee." By B. STEWART. Communicated by the Meteorological Committee. Received June 3, 1868.

In judging of the value of an instrument, such as an aneroid, it is not the mere extent of difference between its indications and those of a standard barometer that ought to guide us; but it is rather the constancy of its indications under the various circumstances to which it may be subjected, that determines its value.

An aneroid may differ from a standard barometer at the ordinary pressure, and to a greater extent at other pressures; but provided these differences can be well ascertained and remain constant, such an instrument ought to be regarded as valuable, just as much as a chronometer of known constancy, but of which the rate is wrong.

The circumstances which may be supposed to affect the indications of an aneroid may be classed under three heads, namely :—

(1) Time.
(2) Temperature.
(3) Sudden variations of pressure.

(1) *Time.*—Of the influence of time, I am not able to say much; Captain Henry Toynbee has allowed me to examine the various readings of an aneroid, which he carried about with him for many years in his voyages, and constantly compared with a standard barometer.

This aneroid (which I shall call No. 1) was between 4 and 5 inches in diameter, and was compensated for temperature.

In July 1860, as compared with a standard barometer, it read 0·025 in. too low. In September 1862 it read (at the same temperature) about 0·012 in. too low; while in March 1864 (still at the same temperature) it read about 0·020 in. too low.

This instrument, which was well cared for, and which, being used chiefly on the surface of the ocean, was subjected neither to a very great nor to a very sudden change of pressure, must be allowed to have retained its character with great constancy.

This is the only definite information regarding the effect of time on these instruments which I have received.

(2) *Temperature.*—A good aneroid is generally compensated by its maker for the effects of temperature, and the question to be investigated is, to what extent such compensations are trustworthy. I record the results (obtained at the Kew Observatory) of subjecting six aneroids, each 4½ inches in diameter, made by two different makers, to a very considerable range of temperature.

No. of instrument.	Correction at				
	55° F.	72° F.	78° F.	88° F.	100° F.
2.	—·105	—·135	—·140	—·145	—·145
3.	—·055	—·090	—·095	—·095	—·100
4.	—·095	—·095	—·095	—·080	—·060
5.	—·106	—·106	—·111	—·111	—·111
6.	—·101	—·111	—·111	—·106	—·106
7.	—·061	—·061	—·061	—·061	—·031

These results are, on the whole, very satisfactory, and appear to show that a well-made compensated instrument has its indications comparatively little affected by a very considerable temperature change.

It ought always to be borne in mind that an aneroid is not capable of being read to the same accuracy as a standard barometer, and that the $\frac{1}{100}$ of an inch is a very small quantity. These temperature experiments were made at the ordinary atmospheric pressure.

I am unable to say what effect a change of temperature would have at a diminished pressure.

(3) *Sudden changes of pressure.*—A preliminary investigation, made at the request of Mr. De La Rue, into the behaviour of an aneroid belonging to the Italian Government, seemed to show considerable error at low pressures. For the purpose of investigating the influence of sudden changes of pressure upon the indications of aneroids, I then applied to some of the best known makers of these instruments, for the loan of several, and through their courtesy in lending me a sufficient number, and for a sufficiently long time, I have been enabled to investigate this influence at some length.

In the following experiments, the instruments were, to begin with, suspended vertically, at the usual atmospheric pressure. They were tapped before being read. The pressure was then lowered an inch, and the instrument allowed to remain ten minutes at this pressure before being read, after having again been well tapped.

The pressure was thus reduced an inch every time, being allowed to remain ten minutes at each stage; the instrument was always well tapped before being read, by means of an arrangement contrived for this purpose by Mr. R. Beckley. The exhaustion was carried downwards to 19 inches in the case of those instruments in which the scale was sufficiently great, and the instrument was allowed to remain an hour and a half at its lowest pressure; the air was then admitted an inch at a time, the previous arrangement as to time and tapping being followed.

TABLE I.

Correction at

No. of ane-roid.	Size.	Date of trial.	30 inches.		29 inches.		28 inches.		27 inches.		26 inches.		25 inches.	
			Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.
8.	4½ inches.	June 1867.	*	·00	-·10	+·07	-·12	+·10	-·10	+·14	-·10	+·15	-·06	+·19
9.	4½ inches.	June 1867.		+·03	-·17	+·03	-·17	+·06	-·17	+·10	-·16	+·10	-·18	+·11
8.	2nd trial.	July 1867.		+·06	-·16	+·09	-·15	+·10	-·12	+·14	-·12	+·19	-·07	+·22
9.	2nd trial.	July 1867.		+·07	-·12	+·07	-·10	+·10	-·07	+·13	-·07	+·17	-·07	+·15
10.	2½ inches.	June 1867.		+·06	-·15	+·09	-·15	+·12	-·12	+·17	-·08	+·19	-·06	+·22
11.	2⅜ inches.	July 1867.		-·03	-·20	-·05	-·21	·02	-·22	-·03	-·22	·00	-·19	+·03
12.	2 inches.	July 1867.		·00	-·19	+·02	-·19	+·06	-·18	+·05	-·13	+·12	-·10	+·14
13.	2 inches.	July 1867.		-·19	-·44	-·16	-·41	-·06	-·36	·00	-·42	·00	-·35	·00
14.	4½ inches.	June 1867.		+·06	-·10	+·07	-·08	+·11	-·03	+·15	-·01	+·16	-·01	+·16
15.	4 inches.	August 1867.		+·01	-·11	+·03	-·15	·00	-·15	+·01	-·14	+·03	-·12	+·03
16.	2½ inches.	June 1867.		+·04	-·12	+·03	-·10	+·06	-·10	+·07	-·06	+·10	-·02	+·13
17.	2 inches.	June 1867.		+·15	-·10	+·20	-·05	+·29	+·02	+·37	+·08	+·44	+·13	+·46

No. of ane-roid.	Size.	Date of trial.	24 inches.		23 inches.		22 inches.		21 inches.		20 inches.		19 inches.	
			Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.	Down.	Up.
8.	4½ inches.	June 1867.	-·07	+·20	·00	+·23	+·04	+·23	+·07	+·21	+·12	+·21	+·18	+·18
9.	4½ inches.	June 1867.	-·17	+·11	-·14	+·09	-·10	+·11	-·04	+·11	+·01	+·10	+·05	+·05
8.	2nd trial.	July 1867.	-·07	+·24	-·04	+·27	+·01	+·25	+·03	+·26	+·09	+·27	+·16	+·25
9.	2nd trial.	July 1867.	-·08	+·15	-·08	+·14	-·06	+·12	-·03	+·16	·00	+·16	+·05	+·13
10.	2½ inches.	June 1867.	-·13	+·24	-·03	+·20	·00	+·21	+·06	+·20	+·12	+·17	+·15	+·17
11.	2⅜ inches.	July 1867.	-·16	+·06	-·15	+·08	-·15	+·11	-·12	+·09	-·09	+·07	-·06	+·17
12.	2 inches.	July 1867.	-·12	+·14	-·11	+·15	-·05	+·24	+·02	+·24	+·08	+·27	+·07	+·26
13.	2 inches.	July 1867.	-·34	·00	-·33	·00	-·29	+·01	-·26	·00	-·18	·00	+·13	-·05
14.	4½ inches.	June 1867.	+·01	+·13	-·02	+·04								
15.	4 inches.	August 1867.	-·05	+·08	+·01	+·09								
16.	2½ inches.	June 1867.	+·01	+·12	+·04	+·10								
17.	2 inches.	June 1867.	+·18	+·49	+·28	+·48								

* Inadvertently in these experiments a single observation in the receiver at the ordinary pressure before exhaustion was not made, but the reading at this pressure was supposed to be represented by the mean of those readings made in the open air for several days before the experiment. As, however, such readings are not strictly comparable with those made in the receiver, they have been omitted.

This Table may be better followed by considering, in the first place, the

down readings, and by supposing each aneroid right to start with (say, right at 29 inches), that is to say, by correcting each instrument for index error.   We thus obtain :—

TABLE II.

Correction for the Down readings of the Aneroids of Table I., supposed right at 29 inches.

No. of aneroid.	Size.	Date of trial.	29 inches.	28 inches.	27 inches.	26 inches.	25 inches.	24 inches.	23 inches.	22 inches.	21 inches.	20 inches.	19 inches.
8.	4½ inches..	June 1867	·00	−·02	·00	·00	+·04	+·03	+·10	+·14	+·17	+·22	+·28
9.	4½ inches..	June 1867	·00	·00	·00	+·01	−·01	·00	+·03	+·07	+·13	+·18	+·22
8.	2nd trial ..	July 1867	·00	+·01	+·04	+·04	+·09	+·09	+·12	+·17	+·19	+·25	+·32
9.	2nd trial ..	July 1867	·00	+·02	+·05	+·05	+·05	+·04	+·04	+·06	+·09	+·12	+·17
10.	2½ inches..	June 1867	·00	·00	+·03	+·07	+·09	+·02 ?	+·12	+·15	+·21	+·27	+·30
11.	2¾ inches..	July 1867	·00	−·01	−·02	−·02	+·01	+·04	+·05	+·05	+·08	+·11	+·14
12.	2 inches ..	July 1867	·00	·00	+·01	+·06	+·09	+·07	+·08	+·14	+·21	+·27	+·26
13.	2 inches ..	July 1867	·00	+·03	+·08	+·02	+·09	+·10	+·11	+·15	+·18	+·26	+·31
14.	4½ inches..	June 1867	·00	+·02	+·07	+·02	+·09	+·11	+·08				
15.	4 inches ..	August 1867 ..	·00	−·04	−·04	−·03	−·01	+·06	+·12				
16.	2½ inches..	June 1867	·00	+·02	+·02	+·06	+·10	+·13	+·16				
17.	2 inches ..	June 1867	·00	+·05	+·12	+·18	+·23	+·28	+·38				

If now we separate the results of Table II. into two sets, one comprising large (4 to $4\frac{1}{2}$ inch) aneroids and the other small instruments, we shall find the mean down correction for large aneroids to be as follows.

	29 in.	28 in.	27 in.	26 in.	25 in.	24 in.	23 in.	22 in.	21 in.	20 in.	19 in.
Mean correction for large aneroids, graduated to 19 in. ..	·00	·00	+·02	+·03	+·04	+·04	+·07	+·11	+·14	+·19	+·25
23 in.	·00	−·02	+·02	+·03	+·04	+·08	+·10				

In like manner we shall find for small aneroids, supposed right at 29 inches, the following mean correction :—

	29 in.	28 in.	27 in.	26 in.	25 in.	24 in.	23 in.	22 in.	21 in.	20 in.	19 in.
Mean correction for small aneroids, graduated to 19 in. ..	·00	+·01	+·02	+·03	+·07	+·07	+·09	+·12	+·17	+·23	+·25
23 in.	·00	+·03	+·07	+·12	+·16	+·20	+·27				

It will be seen that there are two instances in which the same instrument has been twice experimented on. Assuming that the mean of the two experiments represents the true correction for each of these instruments, we find :—

	29 in.	28 in.	27 in.	26 in.	25 in.	24 in.	23 in.	22 in.	21 in.	20 in.	19 in.
No. 8. Mean correction, deduced from two experiments	·00	−·01	+·02	+·02	+·06	+·06	+·11	+·15	+·18	+·23	+·30
Mean *minus* first determination ..	·00	+·01	+·02	+·02	+·02	+·03	+·01	+·01	+·01	+·01	+·02

In like manner :—

	29 in.	28 in.	27 in.	26 in.	25 in.	24 in.	23 in.	22 in.	21 in.	20 in.	19 in.
No. 9. Mean of two experiments	·00	+·01	+·02	+·03	+·02	+·02	+·03	+·06	+·11	+·15	+·20
Mean *minus* first determination ..	·00	+·01	+·02	+·02	+·03	+·02	·00	−·01	−·02	−·03	−·02

We see from these results that if aneroids, right to begin with, be sub-

jected to a decrease of pressure similar to that to which they were subjected in these experiments—

(1) That a well-constructed large aneroid will not go far wrong down to 24 inches, but after that pressure its reading will be considerably lower than that of a standard barometer, so that a large positive correction will have to be applied.

(2) That small aneroids are less trustworthy than large ones, and probably cannot be trusted below 26 inches.

(3) That if previous experiments are made upon an aneroid, we are enabled by this means to obtain a table of corrections which, when applied to future observations with the same instrument, will most probably present us with a much better result than had we not verified our instrument at all, and that by this means we may use our instrument down to 19 inches with very good results.

Let us now consider the up readings of these instruments, and let us suppose that each instrument is right to begin with, that is to say, while remaining an hour and a half at its lowest reading.

These corrections and up readings are exhibited in the following Table :—

TABLE III.

No. of ane-roid.	Correction for the up readings of the aneroids of Table I. supposed right with standard at lowest reading.											
	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
8.	·00	+·03	+·03	+·05	+·05	+·02	+·01	−·03	−·04	−·08	−·11	−·18
9.	·00	+·05	+·06	+·06	+·04	+·06	+·06	+·05	+·05	+·01	−·02	−·02
8.	·00	+·02	+·01	·00	+·02	−·01	−·03	−·06	−·11	−·15	−·16	−·19
9.	·00	+·03	+·03	−·01	+·01	+·02	+·02	+·04	·00	−·03	−·06	−·06
10.	·00	·00	+·03	+·04	+·03	+·07	+·05	+·02	·00	−·05	−·08	−·11
11.	·00	−·04	−·02	·00	−·03	−·05	−·08	−·11	−·14	−·13	−·16	−·14
12.	·00	+·01	−·02	−·02	−·11	−·12	−·12	−·14	−·21	−·20	−·24	−·26
13.	·00	+·05	+·05	+·06	+·05	+·05	+·05	+·05	+·05	−·01	−·11	−·14
14.	...	...	...	...	·00	+·09	+·12	+·12	+·11	+·07	+·03	+·02
15.	...	...	...	...	·00	−·01	−·06	−·06	−·08	−·09	−·06	−·08
16.	...	...	...	...	·00	+·02	+·03	·00	−·03	−·04	−·07	−·06
17.	...	...	...	...	·00	+·01	−·02	−·04	−·11	−·19	−·28	−·33

Hence we find the mean up correction for large aneroids :—

	19 in.	20 in.	21 in.	22 in.	23 in.	24 in.	25 in.	26 in.	27 in.	28 in.	29 in.	30 in.
Supposed right at 19 in.	·00	+·03	+·03	+·03	+·03	+·02	+·01	·00	−·03	−·06	−·08	−·11
Supposed right at 23 in.	..	..	..	..	·00	+·04	+·03	+·03	+·01	−·01	−·02	−·03

In like manner for small aneroids we have the following result :—

	19 in.	20 in.	21 in.	22 in.	23 in.	24 in.	25 in.	26 in.	27 in.	28 in.	29 in.	30 in.
Right at 19 in. ..	·00	·00	+·01	+·02	−·01	−·01	−·02	−·04	−·07	−·10	−·15	−·16
Right at 23 in. ..	..	..	..	..	·00	+·01	·00	−·02	−·07	−·11	−·12	−·19

As before, there are two instances in which the same instrument was twice tried ; assuming the mean of the two trials to represent the truth, we find—

	19 in.	20 in.	21 in.	22 in.	23 in.	24 in.	25 in.	26 in.	27 in.	28 in.	29 in.	30 in.
No. 8. Mean correction..	·00	+·02	+·02	+·02	+·03	·00	−·01	−·04	−·07	−·11	−·12	−·18
Mean *minus* first determination ..	·00	−·01	−·01	−·03	−·02	−·02	−·02	−·01	−·03	−·03	−·01	·00

In like manner—

	19 in.	20 in.	21 in.	22 in.	23 in.	24 in.	25 in.	26 in.	27 in.	28 in.	29 in.	30 in.
No. 9. Mean correction..	·00	+·04	+·04	+·03	+·03	+·04	+·04	+·04	+·02	−·01	−·04	−·04
Mean *minus* first determination ..	·00	−·01	−·02	−·03	−·01	−·02	−·02	−·01	−·03	−·02	−·02	−·02

We may learn from these results that if aneroids which have been subjected for at least one hour and a half to the lowest pressures which they register, have the pressure increased by means of the gradual introduction of air into the receiver, after the manner already described.

(1) That a well-constructed large aneroid will not go far wrong for about 8 inches above the lowest pressure.

(2) That in this respect small aneroids are somewhat less trustworthy than large ones.

(3) That if the instrument read be previously tested and its corrections ascertained, we may consider it trustworthy (making use of these corrections) for up readings throughout a greater range than if it had not been so tested.

I come now to consider whether a rapid change of pressure affects an aneroid after the experiment has been completed.

The following Table will exibit the results obtained in this direction.

TABLE IV.

	1st Ex. 8.	1st Ex. 9.	2nd Ex. 8.	2nd Ex. 9.	10.	11.	12.	13.	14.	16.
Correction before experiment	−·10	−·12	−·13	−·09	−·12	−·11	−·13	−·47	−·04	−·05
Immediately after experiment	·00	+·03	+·06	+·07	+·06	−·03	·00	−·19	+·06	+·04
18 hours after experiment	−·07	−·03	+·04	+·02	..	−·10	−·07	−·34	+·01	+·01
48 hours after experiment	−·08	−·04	..	..	−·03	..	..	−·37	..	..
3 days after experiment	−·08	−·05	..	..	..	..	..	..	−·01	−·01
3 weeks after experiment	−·13	−·10	..	..	−·11	..	..	..	−·07	−·06

It thus appears that if an instrument reads correctly before it is put into the receiver it will read too low immediately afterwards, and that it may be some considerable time before it recovers its previous reading. The instrument cannot, therefore, be safely trusted for absolute determinations if it has been recently exposed to rapid changes of pressure.

The experiments hitherto recorded, in which an inch of pressure has been taken away or added every ten minutes, are perhaps analogous to ascents in a balloon, or descents from a mountain ; they are not, however, precisely analogous to mountain ascents, since a longer time than 10 minutes is usually taken to produce a change of pressure equal to 1 inch.

At the suggestion of Mr. Charles Brooke, a couple of aneroids were tested in April 1868, with the view of rendering the experiment more analogous to a mountain ascent.

The pressure was reduced by half an inch at a time and at intervals of 30 minutes, the aneroids being well tapped.

The following corrections were obtained for down readings (instruments supposed right at 30 inches).

TABLE V.

At	No. 8.	No. 9.	At	No. 8.	No. 9.
inches.			inches.		
30·	·00	·00	23·5	+·08	−·02
29·5	·00	−·03	23	+·11	−·03
29	·00	−·04	22·5	+·12	−·01
28·5	·00	−·03	22	+·14	·00
28	·00	−·03	21·5	+·16	+·02
27·5	·00	−·02	21	+·17	+·04
27	....	....	20·5	+·20	+·06
26·5	·00	−·02	20	+·22	+·07
26	+·01	−·02	19·5	+·25	+·09
25·5	+·04	−·02	19	+·27	+·11
25	+·05	−·04			
24·5	+·06	−·02			
24	+·05	−·01			

These results, when compared with the previous determinations for these same instruments, would seem to show that a somewhat better result is obtained when the exhaustion is carried on more slowly, and hence that the corrections depend, to a considerable extent, on the nature of the treatment received. No. 8 seems to be more constant under different treatment than No. 9.

From all these experiments we may perhaps conclude as follows :—

(1) A good aneroid of large size may be corrected for temperature by an optician, so that the residual correction shall be very small.

(2 a) If an aneroid correct, to commence with, be used for a balloon or mountain ascent, it will be tolerably correct for a decrease of about 6 inches of pressure.

(2 β) A large aneroid is more likely to be correct than a small one.

(2 γ) The range of correctness of an instrument used for mountain ascents may be increased by a previous verification, a table of corrections being thus obtained.

(3 a) If an aneroid have remained some time at the top of a mountain, and be supposed correct to start with, then it will give good results for about 8 inches of increase of pressure.

(3 β) A large aneroid is more likely to be correct than a small one.

(3 γ) If the aneroid has been previously verified, it is likely to give a better result.

(4) After being subjected to sudden changes of pressure the zero of an aneroid gradually changes, so that under such circumstances it ought only to be used as a differential and not as an absolute instrument, that is to say, used to determine the distance ascended, making it correct to begin with, or to ascertain the distance descended, making it correct to begin with, it being understood that the instrument ought to be quiescent for some time before the change of pressure is made.

Before concluding I ought to mention that most of the experiments herein described were undertaken and executed in a very careful manner by Mr. T. W. Baker.

XVI. "Contributions to Terrestrial Magnetism, No. XI." By General SABINE, R.A., P.R.S., &c. Received June 18, 1868.

(Abstract.)

This number of the Contributions of Terrestrial Magnetism contains the completion of the Magnetical Survey of the South Polar Regions, undertaken by Her Majesty's Government in 1840–1845 at the joint instance of the Royal Society and the British Association for the Advancement of Science. The observations themselves, and their provisional discussion, have already been given in the previous numbers, V., VI., VIII., and X. of the Contributions. The present number contains a general review of